The New Minneapolis I-35W Bridge

Designed and Built in Only 11 Months

By Kevin L. Western, P.E., Alan R. Phipps, P.E., and Christopher J. Burgess, P.E.

Curved pier shapes, white color, open traffic railing and natural stone abutment wall surfaces were among the items selected by the community at a Design Charette held 16 days after the contract award. Courtesy of FIGG, Tim Davis Photographer.

At 5:00 a.m. on September 18, 2008, just 11 months after notice-to-proceed was given by the Minnesota Department of Transportation (Mn/DOT), traffic flowed across the Mississippi River on the new I-35W Bridge in Minneapolis. This 1,223-foot long bridge features a post-tensioned box girder superstructure with a precast main span of 504 feet, constructed of high performance concrete. Separate parallel structures carry northbound and southbound traffic, each comprised of two concrete box girders joined together to provide a 90-foot 4-inch wide deck. Together, the structures accommodate 10 lanes of traffic with 13- and 14-foot shoulders, and are designed to add rapid bus or light rail transit in the future.

To accelerate the replacement of this critical link in the Interstate system while ensuring quality, Mn/DOT used a best value design/build selection process which evaluated cost, schedule and technical proposals for how well they achieved the project goals. The team of Flatiron-Manson Joint Venture, with FIGG as the design engineer, was selected by Mn/DOT. Out of the four proposals received, the Flatiron-Manson/FIGG proposal was the only concrete bridge.

The bridge was conceived as a functional sculpture designed to complement the context of the area. A theme of "Arches – Water – Reflection" was chosen to express the design concept. Arches from the historic structure type seen along this stretch of the Mississippi River, Water for the significant crossing of the Mississippi River, and Reflection for both the literal reflection seen in the bridge forms and water surface of the river, and the spiritual reflection invoked by the history of the bridge site. Using the theme as a unifying context, a design charrette was held with 88 members of the community just 16 days after the contract award. Options were provided to the charette participants for selection including pier shape, bridge color, feature lighting, railing and abutment wall treatments. This allowed the community to determine how the new bridge could best articulate their creativity and values, even with an accelerated design/build project.

Overcoming Schedule and Site Challenges

Implementing the bridge concept required overcoming two major challenges: completing the emergency replacement bridge in no more than 15 months (by December 24, 2008), and situating the new bridge around the many site constraints. Despite the already accelerated schedule, the Flatiron-Manson/FIGG team focused on achieving an even faster completion while providing a high strength sustainable bridge designed to last over 100 years. The design needed to allow construction work in several areas simultaneously by multiple shifts seven days a week. For the main bridge, the solution was a precast segmental concrete main span combined with back spans that were cast-in-place on falsework. Work progressed separately on these three elements until they were joined with erection of the precast segments to create the finished bridge.

Site constraints that affected where piers and abutments could be placed included the Mississippi River, the foundations from the previous bridge, several roads and trails, large drainage tunnels under the bridge on each side of the river, a historic stone retaining wall, a railroad, a large area of capped hazardous materials, and various utilities. The substructure locations were carefully located to accommodate these site elements.

The north back span pier (Pier 4) was a particular challenge. Design work had proceeded with preliminary survey data, but once the debris

from the previous bridge was removed and accurate survey data obtained, it was discovered that the planned location of Pier 4 conflicted with the existing historic stone wall at the site. As a result, the design location of Pier 4 was moved approximately 20 feet towards the river, which created an unbalanced back span on the north side. Normally the ratio of back to main-span length should be within 0.60 to 0.70. In this instance it is 0.47. To compensate, the thickness of the box girder webs and bottom slab were increased, providing the necessary counter-weight for cantilevered construction of the main-span without uplift at Pier 4.

At some locations it was not possible to avoid the constraints and the new bridge had to be adapted to the existing site features. For instance, at the north river bank the main pier for the northbound bridge (Pier 3) had to be positioned over a large 22- by 22-foot storm outlet, which is skewed approximately 45 degrees to the footing. The outlet is at the center of the footing and flairs to its widest point directly under the footing. Moving the storm outlet would have required too much time and expense. So the eight-foot diameter drilled shaft foundations were placed on either side of the storm outlet, and the footing was designed to straddle over the top of the outlet while remaining structurally isolated from it.

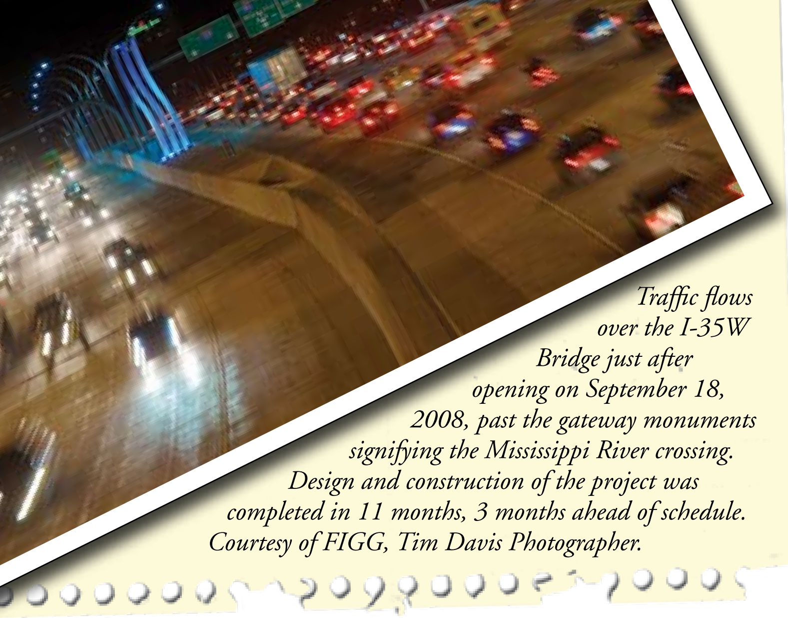
Durability and Sustainability for a Minimum Service Life of 100 Years

Minnesota DOT's vision for the bridge included a minimum design service life of 100 years, one third longer than for typical bridges. A Corrosion Protection Plan was developed by the construction and design team to frame the design strategy for achieving this requirement. Some of the key elements of the strategy were:

- Concrete bridge with post-tensioning in two directions, with 250 psi residual compression in the longitudinal top surface of the box girder.
- High performance concrete containing silica fume and fly ash for low permeability.
- Integral concrete wearing surface.
- Post-tensioning durability system with polyethylene ducts, prepackaged thixotropic grout and multiple layer anchorage protection.
- Structure health monitoring system, including deck corrosion potential sensors.

High Performance Concrete (HPC) mixes were developed for the project as part of the overall corrosion protection strategy to meet the unique requirements of individual bridge elements. One use was the seven and eight foot diameter drilled shafts up to 95 feet deep that support the main bridge piers. To assure monolithic high quality concrete with tremie placement into slurry-filled heavily reinforced shafts, self-consolidating concrete (SCC) was used. This was the first large scale use of cast-in-place SCC for Mn/DOT. To control temperatures in the large diameter shafts during curing, fly ash and slag were used for the majority of the cementitious material which reduced

The 504' main span over the Mississippi River is made of 120 precast segments that were erected in just 47 days. The segments were precast in forms built on the closed Interstate roadbed just south of the bridge. Courtesy of FIGG, Tim Davis Photographer.



Traffic flows over the I-35W Bridge just after opening on September 18, 2008, past the gateway monuments signifying the Mississippi River crossing. Design and construction of the project was completed in 11 months, 3 months ahead of schedule. Courtesy of FIGG, Tim Davis Photographer.

the heat of hydration approximately 50%. With cylinder compressive strengths up to 10,000 psi, compared to the design requirement of 5,000 psi, the performance of the SCC mix used in the drilled shafts exceeded expectations.

Mixtures for footings and piers were proportioned for mass concrete and durability through the use of fly ash and slag. This was important, since the least concrete dimension was 13 feet for the main pier footings and 16 feet for the main pier columns. Also, being adjacent to the Mississippi River, these elements are subject to significant moisture exposure. A mass concrete plan was developed for each element which included thermal monitoring, concrete mix modifications (cement substitution, chilled water, cooled aggregates, etc.), pour sequence/lift heights, form insulation, and/or cooling tubes. The combination of a high quality monolithic element and low permeable concrete with these mixes resulted in a strong substructure that is expected to stand the test of time.

Superstructure concrete consisted of a 6,500 psi mix with fly ash and silica fume for low permeability. The tested rapid chloride permeability of this mixture is very low, with results averaging approximately 250 coulombs passed at 28 days, well below the 2000 coulombs requirement of the Corrosion Protection Plan. Silica fume will also increase the impedance of the concrete, thereby inhibiting any corrosion that may occur in the future. The mixture has low shrinkage, minimizing stresses due to shrinkage and associated cracking. Strength results also exceed expectations, with average 28-day strength of approximately 8,000 psi, 23 percent above design requirements.

Precast Segments Complete 504′ Main Span in 47 Days

Construction of the bridge started with installation of the foundation test shaft on November 1, 2007, just 17 days after construction operations began. Throughout the winter, crews built the bridge foundations and substructures using enclosures with heated air to control the environment around the foundations, piers and abutments.

While substructure work (and later the cast-in-place spans over land) was underway, four lines of box girders for the 504-foot main span over the river were precast off-line. Taking advantage of an existing site feature to save time, Flatiron-Manson set up a casting yard on the closed interstate highway pavement just south of the bridge and immediately constructed the majority of the formwork with timber. Prefabricated metal buildings on rollers were used to provide shelter for the precasting operations through the cold Minnesota winter. The first segment was cast on January 30, 2008, only 107 days after construction started, when the high temperature was -2 degrees F. A total of 120 precast box girder segments, varying from 25 feet to 11 feet in depth, were produced in eight long-line segment casting beds in 128 days.

After curing, segments were removed from the forms and transported by trailer to a nearby staging area at the bank of the Mississippi River. There they were prepared for erection, loaded onto a barge, and floated to the bridge location. A barge mounted ringer crane then lifted the segments for attachment to the completed cast-in-place side spans. Main span construction proceeded from the banks towards the center of the river in one-direction cantilever, with a maximum of six segments weighing up to 200 tons each erected in a single day. The last segment was placed on July 10, 2008, completing the main span in only 47 days.

"Smart Bridge" Sensor System Enhances Bridge Inspections

The completed bridge incorporates "Smart Bridge" technology to enhance bridge inspections and assist in the advancement of bridge design. In a partnership between Mn/DOT, the Federal Highway Administration, and the University of Minnesota, over 320 sensors throughout the structure monitor the bridge behavior. These include vibrating wire strain gages embedded in the concrete of the foundations, piers and superstructure, long gauge fiber optic strain gauges, accelerometers, linear potentiometers, and corrosion potential sensors embedded in the wearing surface. The data is transmitted via fiber optic cables and collected by the University.

Completed Three Months Early

Two gleaming white concrete sculptures, each comprised of three wavy columns, tower 30 feet high at each end of the bridge in a vertical interpretation of the universal symbol for water. The sculptures are made with a pioneering self-cleaning photocatalytic cement that is efficient in destroying atmospheric pollutants, and are the first high-profile North American application of this material. These symbols serve as markers for travelers that they are crossing the very significant Mississippi River.

Minnesota DOT's vision for safety, quality and innovation for the new bridge, incorporating the inspiration of the community, was a reality just eleven months (339 days) after the start of the project. While the strategy of using precast segments to construct a bridge in multiple areas simultaneously enabled this accomplishment, it was the extraordinary efforts of a committed team between Mn/DOT, FHWA, Flatiron-Manson, the design team and the many subcontractors and suppliers that made this project a triumphant success.▪

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Alan Phipps, P.E. was the Design Manager for the design-build team on the I-35W Bridge project. He is currently the Director of Operations for FIGG in their Tallahassee, Florida, headquarters and is a registered engineer in 16 states.

Chris Burgess, P.E. is a Principal Bridge Engineer with FIGG. Chris was the lead technical designer of the I-35W Bridge and provided on-site engineering assistance during main span construction. He is a registered professional engineer in 14 states.

Project Team

Owner: *Minnesota DOT*
Bridge Designer: *FIGG*
Design/Build Contractor: *Flatiron-Mason, JV*